Yonago Acta medica 2015;58:115–122 *Original Article*

Water Quality Evaluation of PET Bottled Water by Mineral Balance in the Northeast Asian Region: A Case Study of South Korea

Daisuke Houri* and Chung Mo Koo†

**Division of Medical Education, Department of Social Medicine, School of Medicine, Tottori University Faculty of Medicine, Yonago 683-8503, Japan and †Faculty of Economics and International Trade, Kangwon National University, Chuncheon 200-701, South Korea*

ABSTRACT

Background The past few years have seen a demand for drinking water in contemporary society with a focus on safety and taste. Mineral water is now marketed as a popular commercial product and, partly due to health concerns, the production.

Methods For the study, a comparison was carried out of water samples from 9 types of polyethylene terephthalate (PET) bottled water sold in South Korea as well as from tap water in the cities of Seoul and Chuncheon. These were compared with samples of Japanese PET bottled water in order to determine shared commonalities and identify individual characteristics. To evaluate water quality objectively, we quantified the elements contained in the water samples. Samples were assessed not with the usual sensory evaluation but with the evaluation approach advocated by Hashimoto et al. which employs the Water Index of Taste and the Water Index of Health. The levels of water quality obtained were compared with the "Prerequisites for Tasty Water" and the "Standards for Tasty Water" devised for city water.

Results The PET Bottled water varieties analyzed in this study—*Seoksu*, *Icis*, *Bong Pyong*, *Soon Soo 100*, *Dong Won Saem Mul*, *GI JANG SOO* and *DIAMOND*—showed the Water Index of Taste ≥ 2.0 and the Water Index of Health ≥ 5.2, which we classified as tasty/healthy water. *SamDaSoo* and *NamiNeral* can be classified as tasty water due to their values of the Water Index of Taste ≥ 2.0 and the Water Index of Health < 5.2.

Conclusion The South Korean PET bottled water studied here fulfills the "Water Index of Taste," "Water Index of Health," "Standard for Tasty Water" and "Prerequisites for Tasty Water" that Japanese people value for city water. We can conclude that bottled water which meets water quality requirements will be considered good-tasting by a majority of people.

Key words bottled water; mineral water; South Korea; taste; water quality

The past few years have seen a demand for drinking water in contemporary society with a focus on safety and taste. Mineral water is now marketed as a popular commercial product and, partly due to health concerns, the production and consumption of various mineral waters have steadily increased.

In South Korea, where urbanization has progressed rapidly along with the country's economic growth, the custom of drinking tap water directly from the faucet has decreased as the quality of city water has deteriorated. In Japan, in contrast, tap water can still be drunk directly from the faucet. However, due to fears related to water safety, to the popularity of super-soft water and to consumer preferences for hard water for dieting purposes, most drinking water comes from polyethylene terephthalate (PET) bottled water.

One research study so far has been reported by Choi et al.[1] who analyzed the mineral ingredients of South Korean PET bottled water for the whole country. However, the names of individual PET bottle brands were not mentioned. Moreover, this report[1] analyzed PET bottled water that was purchased between 1995 and 1996, just after the sale of drinking water in containers in South Korea was permitted in 1994. It can be assumed that the PET bottled water samples studied included both newly sold water as well as water whose sale had been discontinued. As yet, there have been no articles about Korean bottled water published in English which deal with water indexes of taste and of health.

The study here analyzed PET bottled water sold in LOTTE Mart in Seoul, a major South Korean bottled water supplier, with each PET bottle name clearly shown.

For the study, a comparison was carried out of water samples from 9 types of PET bottled water sold in South Korea as well as from tap water in the cities of Seoul and Chuncheon. These were compared with samples of Japanese PET bottled water[2, 3] in order to determine shared commonalities and identify individual characteristics. To evaluate water quality objectively, we quantified the elements contained in the water samples.

Corresponding author: Daisuke Houri, PhD
houri@med.tottori-u.ac.jp
Received 2015 June 26
Accepted 2015 July 27
Abbreviation: PET, polyethylene terephthalate

Samples were assessed not with the usual sensory evaluation[4] but with the evaluation approach advocated by Hashimoto et al.[5, 6] which employs the Water Index of Taste and the Water Index of Health. The levels of water quality obtained were compared with the "Prerequisites for Tasty Water" and the "Standards for Tasty Water" devised for city water by the "Tasty Water Research Association" (Tokyo, Japan) of the former Japanese Health and Welfare Ministry.[7]

MATERIALS AND METHODS

Samples for analysis

PET bottled water that is currently available for purchase was used for the analysis. The samples were randomly selected by a colleague in South Korea from PET bottled water sold in LOTTE Mart (Seoul Station store). These were then sent by air mail to Japan for analysis. The varieties of South Korean PET bottled water analyzed were *Sam Da Soo* (Jeju Special Self-Governing Province Development, Jeju-si, South Korea), *Seoksu* (Hitejinro Beverage, Seoul, South Korea), *Icis* (Lotte Chilsung Beverage, Seoul, South Korea), *Bong Pyong* (Hae-Tae Beverage, Pyeongchang, South Korea), *Soon Soo 100* (Coca-Cola Korea, Yangsan-si, South Korea) and *Dong Won Saem Mul* (Dong-won F&B, Seoul, South Korea) as well as city water from general apartments in the city of Seoul (South Korea). The tap water came from a faucet in the apartment of a colleague in Seoul, was placed in an empty PET bottle, and was sent by airmail to Japan for analysis. Since LOTTE Mart is a respected South Korean retail store, the PET bottle samples purchased there were assumed to be popular brands with a high degree of trust.

PET bottled water from Chuncheon City was also analyzed. This water, which comes from a local water source in the Chuncheon City region, was purchased there in 2013 from a local convenience store. The PET bottled water varieties analyzed were *NamiNeral* (Jae Ewon, Hamyeon, South Korea), *GI JANG SOO* (Donghae Water, Seoul, South Korea), *DIAMOND* (Coca-Cola Korea, Yangsan-si, South Korea) and city water in Chuncheon City. The tap water in Chuncheon City was obtained from a faucet in the kitchen of a restaurant in Chuncheon Myeongdong Dakagalbi Street in the central part of the city. It was placed in an empty PET bottle, and sent by airmail to Japan for analysis.

Analysis items, methods and devices

The items analyzed for each water sample were total solids, hardness, potassium permanganate consumption, free carbonate, residual chlorine, threshold odor number, odor, pH, Fe, Cl^-, SO_4^{2-}, Ca, K, SiO_2, Mg and Na. Table 1 shows these items and the assay and devices used.

For this study, water analysis was carried out by the Tottori Health Service Association (Tottori, Japan), the officially registered organization for Tottori Prefecture,

Table 1. Analytical methods and analyzers

Analysis Items	Analysis Methods		Analyzers
SiO_2	Standard methods for the examination of water (2001)	ICP-AES	HITACHI P-4010*
SO_4^{2-}	Standard methods for the examination of water (2001)	Ion chromatograph method	LC-10AD†
Hardness	Standard methods for the examination of water (2001)	Titration method	
pH	Standard methods for the examination of water (2001)	Glass electrode method	HORIBA F-13‡
Total solids	Standard methods for the examination of water (2001)	Gravimetric method	
Free carbonate	Standard methods for the examination of water (2001)	Titration method	
Potassium permanganate consumption	Standard methods for the examination of water (2001)	Titration method	
Residual chlorine	Standard methods for the examination of water (2001)	DPD method	
Threshold odor number	Standard methods for the examination of water (2001)	Organoleptic method	
Odor	Standard methods for the examination of water (2001)	Organoleptic method	
Fe	Standard methods for the examination of water (2001)	ICP-AES	HITACHI P-4010*
Cl^-	Standard methods for the examination of water (2001)	Ion chromatograph method	LC-10AD†
Na	Calibration curve method	ICP-AES	RIGAKU CIROS CCD§
K	Calibration curve method	ICP-AES	RIGAKU CIROS CCD§
Mg	Calibration curve method	ICP-AES	RIGAKU CIROS CCD§
Ca	Calibration curve method	ICP-AES	RIGAKU CIROS CCD§

*HITACHI P-4010 (Hitachi High-Tech Science, Tokyo, Japan).
†LC-10AD (Shimadzu, Kyoto, Japan).
‡HORIBA F-13 (Horiba, Kyoto, Japan).
§RIGAKU CIROS CCD (Rigaku, Tokyo, Japan).

according to the Standard Methods for Examination of Water (2001)[8]. However, total solids, free carbonate, potassium permanganate consumption, Fe and Cl^- were not analyzed for the three varieties of *NamiNeral*, *GI JANG SOO* and *DIAMOND*. This was because data on the Water Index of Taste and Water Index of Health for these three PET bottles was needed at once for another research project, so these items were not analyzed.

Water Index of Taste and Water Index of Health

Water Index of Taste

The index used to evaluate water taste was the "Water Index of Taste" designed by Hashimoto et al.[5, 6] as well as the "Prerequisites for Tasty Water" and "Standard for Tasty Water" used by the Ministry of Health and Welfare for tap water.

The Water Index of Taste is decided by the balance of Ca, K, SiO_2, Mg, and SO_4^{2-}. In other words, the water index of taste is determined by the proportion of the total amount of Ca, K and SiO_2 as well as the total amounts of Mg and SO_4^{2-}.

Hashimoto et al. have shown, as measured by sensory examination, that Ca, K and SiO_2 improve the taste of nationally representative drinking water and mineral water while Mg and SO_4 worsen the taste. Based on these findings, they proposed this Water Index of Taste. After calculating the Water Index of Taste for drinking water and mineral water, the Water Index of Taste = 2.0 was shown as the border line for water which was or was not tasty.

$$\text{Water Index of Taste} = \frac{Ca + K + SiO_2}{Mg + SO_4}$$

The Water Index of Taste is determined by the above equation. When the Water Index of Taste value is 2.0 or more, the water is judged to be tasty. Water Index of Taste values was obtained for the water quality element of each sample.

Water Index of Health

Hashimoto et al. [5, 6, 9] claim that the presence of Ca in water is an important plus factor for health since it prevents osteoporosis and acts to maintain heart and muscle functions. They claim that Na, in contrast, is a minus factor because a higher Na intake raises the risk factor for arteriosclerosis. They therefore advocate a "Water Index of Health" calculated from the Ca concentration and Na density as health indicators.

$$\text{Water Index of Health} = Ca - 0.87\,Na$$

The Water Index of Health is obtained from the above equation. The Water Index of Health value was determined from water analyses of each sample. When

Table 2. Influence on tap water taste of items in the "Standards for Tasty Water" (A) and "Prerequisites for Tasty Water" (B)

Water quality item	A	B	Influence on tap water taste
Total solids	○	○	Quantity of the mineral left when sample is vaporized. In moderate amounts, this gives a full-bodied mild taste. In greater quantities, the taste worsens as a result of increased astringency, bitterness and salty taste.
Hardness	○	○	Total quantity of the Mg and Ca. With low hardness, water becomes easier to drink. the taste improve when Ca > Mg, and the bitterness increases when the amount of Mg is higher.
Potassium permanganate consumption	○	○	This shows the quantity of organic material. At high amounts, the taste is spoiled due to greater astringency.
Free carbonate	○		This refers to the amount of carbon dioxide dissolved in water. This gives a refreshing taste, but in greater quantities the taste becomes too strong.
Temperature	○		This is one of the key points that determine water taste. At a temperature of 10-15 degrees Celsius, water is perceived as most refreshing.
Residual chlorine	○		This imparts a chlorine smell to water and spoils the taste at high densities.
Threshold odor number	○		Depending on the condition of the water source, the taste can become unpleasant due to the addition of various smells.
Odor		○	When the standard value is "not abnormal," the presence of unusual odors and taste may indicate contamination of water by sewage or factory effluent.
pH		○	This indicates a hydrogen-ion concentration in the solution. For tap water, the standard for acidity or alkalinity is 5.8-8.6. However, a value of 6.7-7 is most suitable for good taste.
Fe		○	The standard value is determined by the amount of iron that leads to a worsening taste in Japanese tea.
Cl^-		○	This refers to the anionic chlorine of the mineral ingredient. This differs from chlorine used for sterilization. The standard value is set from the value that produces the taste of saltiness.

the value of the Water Index of Health is 5.2 or more, the water is judged to be healthy.

Comparison of "Prerequisites for Tasty Water" and "Standard for Tasty Water" for tap water

In April 1984, the Japanese Ministry of Health and Welfare announced its "Prerequisites for Tasty Water." Table 2 shows the data for the taste and features of tap water according to the "Prerequisites for Tasty Water" and "Standard for Tasty Water."

An analysis of tap water said to be either tasty or not tasty was carried out at 30 places around Japan using items from the "Prerequisites for Tasty Water" (B of Table 2: 7 items of total solids, hardness, potassium permanganate consumption, odor, pH, Fe, Cl^-). The results showed that tasty water was shown to have a constant chemical tendency. In June 1984, the "Tasty Water Research Association" of the former Health and Welfare Ministry was established to determine what kind of water is "tasty" and to examine ways to make drinking water more delicious. Its "Standard for Tasty Water"[7] was officially announced in 1985.

This "Standard for Tasty Water" referred to the results of water tasting conducted in each region of Japan and to an analysis of the tap water quality around the country. Water deemed tasty was determined using a questionnaire survey. The quality of those water varieties felt to be tasty by many people was analyzed for selected items (A of Table 2: 7 items of total solids, hardness, potassium permanganate consumption, free carbonate, water temperature, residual chlorine, and threshold odor number) to obtain a standard value. However, for this study, water temperature, residual chlorine and threshold odor number were excluded in the analysis of PET bottled water.

The elements and numerical values for tasty water were calculated using the "Prerequisites for Tasty Water" and "Standard for Tasty Water" with the assumption that this water is safe and pleasant to drink. However, the water quality evaluation items and criteria were different. Currently, seven items in the "Standard for Tasty Water" are generally understood to be the standard requirements for tasty water. Each sample in the study was evaluated for water quality items of both the "Prerequisites for Tasty Water" and the "Standard for Tasty Water."

Table 3. Characteristics and chemical composition of bottled waters and tap waters

mg/L	*Sam Da Soo*	*Seoksu*	*Icis*	*Bong Pyong*	*Soon Soo 100*
Mg (mg/L)	2.5 (1.0–2.8)	2.9 (1.7–5.7)	3.7 (1–6)	2.2 (0.8–5.4)	2.5 (0.4–2.8)
Na (mg/L)	5.8 (4.0–7.2)	4.7 (2.1–9.2)	13.0 (4–40)	6.2 (2.5–10.7)	9.0 (3.9–12.5)
Ca (mg/L)	2.9 (2.2–3.6)	24.0 (15.0–49.6)	27.0 (7–46)	12.0 (5.8–34.1)	13.0 (6.1–24.8)
K (mg/L)	2.0 (1.5–3.4)	1.4 (0.8–2.4)	1.2 (0–2)	0.5 (0.3–1.4)	0.8 (0.1–1.4)
SiO_2 (mg/L)	26.0	11.0	23.0	20.0	22.0
SO_4^{2-} (mg/L)	1.8	7.9	15.0	3.8	5.3
Hardness (mg/L)	17	72 (70–80)	83	40	44
pH	7.4	7.3 (7.4–7.8)	6.7	6.7	7.1
Type of Water	Deep well water	Deep well water	Deep well water	Deep well water	Deep well water
Means of Sterilization	Non-heating sterilization	Non-heating sterilization	Non-heating sterilization	Ozone sterilizing	Ozone sterilizing
Official Name	Natural mineral water	Natural mineral water	Natural mineral water	Mineral water	Mineral water
Place of water intake	San 70, Gyole-ri, Jeochun-eup, Jeju-si	Naeam-li, Gadeuk-myun, Cheongwon-gun. Chung-buk	Mukbang-ri, Sandong, Gimhea-si, Gyeonggi-do	Jinjo-ri, Bongpyong-Myun, Pyoungchang-gun, Gangwon	Chukryung-san, Sudong-myun, Namyangju-si, Gyeonggi-do
Bottling location	Gyole-ri, Jeochun-eup, Jeju-si	149-2 Naeam-li, Gadeuk-myu, Cheongwon-gun. Chung-buk	132-2 Mukbang-ri, Sandong, Gimhea-si, Gyeonggi-do	San 139, Jinjo-ri, Bongpyong-Myun, Pyoungchang-gun, Gangwon	Sudong-myun, Namyangju-si, Gyeonggi-do
Price (Volume)	500 won* (500 mL)	480 won* (500 mL)	450 won* (500 mL)	280 won* (500 mL)	320 won* (500 mL)
URL	http://www.jpdc.co.kr	http://www.seoksu-andpuriss.com	http://company.lottechilsung.co.kr/product/drink_product.jsp?code=109&nPos=030206	n/a	http://www.cocacola.co.kr/Soonsoo/
Water Index of Tast	7.2	3.4	2.7	5.4	4.6
Water Index of Health	-2.2	19.9	15.7	6.6	5.2

The numerical values in parentheses show the numerical values of each mineral element that were displayed on the PET bottle labels. n/a, not applicable. *Korean currency.

RESULTS

Analysis of chemical composition

Table 3 shows an analysis of the chemical composition for each sample.

The value of the mineral element analyzed came from the numerical value displayed on the PET bottles. Most PET bottled water analyzed was generally soft water with a hardness level of 14–83 mg/L. The pH value was neutral at roughly 7.0. Only *GI JANG SOO* showed a pH of 8.0 and a hardness of 110 mg/L. Tap water in both Seoul City and Chuncheon City was soft. The Seoul tap water had a hardness value of 48 mg/L while that in Chuncheon City had a hardness value of 35 mg/L.

Index items of tasty water and healthy water

Water Index of Taste

Table 4 shows the Water Index of Taste for the samples and conditions applied.

When the Water Index of Taste value is 2.0 or more, the water is judged to be tasty. All PET bottled water analyzed was judged to be tasty water. However, neither sample of tap water (from Seoul and Chuncheon) was judged to be tasty.

Water Index of Health

Table 4 shows the Water Index of Health of the sample and the conditions applied.

The Water Index of Health value for PET bottled water from Seoul, except for the *Sam Da Soo* and *NamiNeral* samples, was 5.2 or more. This meets the standard and is assumed to be healthy water.

Comparison of tap water samples in terms of the "Standard for Tasty Water" and "Prerequisites for Tasty Water"

The results for city water quality according to the "Standard for Tasty Water" and "Prerequisites for Tasty Water" are shown in Table 5. The four indices of the conditions applied are summarized in Table 4.

In general, the PET Bottled water samples from South Korea met the "Standard for Tasty Water" and "Prerequisites for Tasty Water."

DISCUSSION

In this paper, the aspect of water quality studied was the main dissolution element. This differs from the evaluation of water quality for beverages issued by public

Dong Won Saem Mul	Tap Water (Seoul)	*NamiNeral*	*GI JANG SOO*	*DIAMOND*	Tap Water (Chuncheon)
2.0 (0.1–6.7)	2.8	0.8 (0.4–1.4)	7.5 (7.97)	1.5	2.5
5.7 (0.9–30.9)	7.2	2.2 (1.0–6.5)	6.0 (5.86)	5.9	4.2
17.0 (1.0–40.1)	14	4.4 (3.8–13.7)	32 (32.58)	20	10
0.6 (0.2–2.1)	2.1	0.6 (0.2–1.2)	0.7 (0.74)	0.6	1.3
10.0	0.4	7.7	6.7	11	3.4
12.0	11	3.9	8.8	4.2	6.1
52	48	14	110	56	35
7.2	7.1	7.2	8.0	7.6	7.2
Deep well water	Running water (City water)	Deep well water	Natural mineral water	Natural mineral water	Mineral water
Ozone sterilizing	Liquid chlorine sterilization	n/a	Non-heating sterilization	Non-heating sterilization	Liquid chlorine sterilization
Mineral water	Tap water	Mineral water	Natural mineral water	Natural mineral water	Tap water
Deajun-ri, Chungsan-myun, Yeoncheon-gun, Gyeonggi-do	Han river	Gapyung-goon, Gyeonggi-do	Donghae-si, Gangwon-do	Chulwon-goon, Gangwon-do	Soyanggang-dam, Chuncheon-dam
212-3 Deajun-ri, Chungsan-myun, Yeoncheon-gun, Gyeonggi-do	164-2, Gooeu-dong, Gwangjin-gu, Seoul (5 more in Seoul)	Gapyung-goon, Gyeonggi-do	459-5, Mangsang-dong, Donghae-si, Gangwon-do	478 Yookdan-ri, Geunnam-myun, Chulwon-goon, Gangwon-do	329-2, Yongsan-ri, Sinbook-eup, Chuncheon-si, Gangwon-do (1 more in Chuncheon
400 won* (500 ml)	561.27 won* (m^2)	n/a	1000 won* (500 mL)	315 won* (500 mL)	n/a
http://www.dongwon-saemmul.co.kr/	http://water.seoul.go.kr/	n/a	www.donghaewater.co.kr	http://www.diamond-water.co.kr	http://water.chuncheon.go.kr/main/main.php
2.0	1.2	2.7	2.4	5.5	1.71
12.0	7.7	2.5	26.8	14.9	6.4

Table 4. Evaluation of each sample according to the four indices

	Water Index of Taste		Water Index of Health		Standards for Tasty Water	Prerequisites for Tasty Water
Sam Da Soo	○ *	7.2		–2.2	3/4†	6/7†
Seoksu	○ *	3.4	○ *	19.9	4/4†	5/7†
Icis	○ *	2.7	○ *	15.7	4/4†	5/7†
Bong Pyong	○ *	5.4	○ *	6.6	4/4†	6/7†
Soon Soo 100	○ *	4.6	○ *	5.2	4/4†	6/7†
Dong Won Saem Mul	○ *	2.0	○ *	12.0	4/4†	5/7†
Tap Water (Seoul)		1.2	○ *	7.7	3/4†	5/7†
NamiNeral	○ *	2.7		2.5	–	–
GI JANG SOO	○ *	2.5	○ *	26.8	–	–
DIAMOND	○ *	5.5	○ *	14.9	–	–
Tap Water (Chuncheon)		1.7	○ *	6.4	2/4†	5/7†

*Cases that meet the requirements of the "Water Index of Taste" or the "Water Index of Health."
†Ratio that meets the requirements of the "Standards for Tasty Water" or the "Prerequisites for Tasty Water."

Table 5. Comparison with Standards and Prerequisites for Tasty Water of bottled waters and tap waters

	Total solids mg/L	Hardness mg/L	Free carbonate mg/L	Potassium permanganate consumption mg/kg	Odor	pH	Fe mg/L	Cl^- mg/L
Standards for Tasty Water	30–200	10–100	3–30	≤ 3	–	–	–	–
Prerequisites for Tasty Water	50–200	≤50	–	≤ 1.5	none	6.0–7.5	≤ 0.02	≤ 50
Sam Da Soo	66	17	2.2	0.9	none	7.4	< 0.03	6.5
Seoksu	110	72	4.0	0.9	none	7.3	< 0.03	6.2
Icis	180	83	10.0	1.1	none	6.7	< 0.03	25.0
Bong Pyong	82	40	6.6	0.9	none	6.7	< 0.03	6.1
Soon Soo 100	98	44	4.4	0.8	none	7.1	< 0.03	3.9
Dong Won Saem Mul	85	52	3.5	0.9	none	7.2	< 0.03	2.0
Tap water (Seoul)	92	48	2.2	2.7	none	7.1	< 0.03	16.0
Tap Water (Chuncheon)	63	45	–	2.0	none	7.2	< 0.03	6.1

health centers. This study provides a chemical analysis of the essential elements of water. Here, the main features are considered.

Criteria for tasty water

The Water Index of Taste is determined by the ratio of mineral elements.

All the South Korean PET Bottled water analyzed met the standards of the Water Index of Taste. Since South Korean mountains are famous for their clear high quality natural water, the PET bottled water collected can be evaluated as tasty water. *Seoksu*, for example, is a very popular variety of mineral water collected at a mountain range from a layer of mica granite and quartz 200m below ground. One source of mineral water, Mt. Sobaek, is said to rank as one of the three major water sources in the world alongside Shasta in the USA and Vichy in France.

Water with a hardness of 50 mg/L is generally liked by many people and water of Ca > Mg is said to have a good taste. Almost all the PET Bottled water in South Korea and Japan analyzed in this study had a hardness of roughly 50 mg/L water with Ca > Mg. All samples more or less met the "Standard for Tasty Water" and "Prerequisites for Tasty Water," although the content of iron ions was somewhat high.

Since South Korea is a peninsula located on the Asian continent, the hardness of South Korean PET Bottle water should be high[1] like Russian water. However, it is actually soft. Choi et al.[1] evaluated the Water Index of Taste ratio of South Korean PET Bottled natural mineral water as 61.9%. Although the PET bottled water samples evaluated in this study were randomly selected at LOTTE Mart, they met all the index standards. The PET bottled water samples studied were collected from all over South Korea, and can be considered

popular brands of water sold in the country's metropolis, Seoul. For this reason, it can be considered that PET bottled water sold in Seoul will be evaluated as tasty by Japanese people. In terms of quality, South Korean PET bottled water can be considered similar to PET bottled water in Japan given its hardness and qualitative index scores.

According to the "Tasty Water Research Association,"[7] "Good taste is an individual matter. Although there is a large amount of individual variation, good-tasting water can be generally regarded as a constant." For most people, water that meets water quality requirements is felt to be tasty. Delicious good tasting water can be considered as universal.

One reason that tap water in Seoul did not meet the Water Index of Taste, compared to other varieties, may be that it had an extremely low SiO_2 value. In order to convince its citizens that its tap water is safe to drink, Seoul City is distributing "Arisu" tap water in PET bottles at civic meetings and city events at no cost. Tap water in Seoul comes from the Han River. It is purified at a water purification plant, then filled in PET bottles and named "Arisu." The safety of "Arisu" has been officially recognized by the water quality authorities of the U.S. Army and Navy[10] and has been judged to be in conformity with the 145 standards promoted by the World Health Organization. Despite this, Seoul citizens do not trust the city's tap water and rarely drink it. This is because of frequent reports in the past about germs in the water, heavy metals mixed in from old water pipes and pollution from rainwater washed in through soil.

Concerning healthy water

PET Bottled water in South Korea, except for the *Sam Da Soo* brand, was found to be tasty and was classified as good, healthy water. It is considered that *Sam Da Soo* did not meet the Water Index of Health because it had low amounts of Ca and because Ca < Na. However, the water source in South Korea for *Sam Da Soo* is Cheju Island. This water, compared with other types of PET bottled water, includes a large amount of SiO_2 and may be popular because it contains 7 μg of vanadium (which is listed on the label).

On the other hand, the Water Index of Health for *GI JANG SOO* was very high. *GI JANG SOO* has a hardness of 110 mg/L and includes extremely minute amounts of yellow ocher clay as well as abundant minerals and enzymes. It has been used in Korea for beauty and health since ancient times.[11] Because Japan has no such yellow ocher layers, there is no water containing amounts of yellow ocher. Another reason that *GI JANG SOO* may have become popular is that it was introduced in the popular Korean TV drama "Dae Jang Geum" as drinking water used in the Imperial Court.

When classified by Hashimoto et al. using the Water Index of Taste and the Water Index of Health, the PET Bottled water varieties analyzed in this study—*Seoksu*, *Icis Bong Pyong*, *Soon Soo 100*, *Dong Won Saem Mul*, *GI JANG SOO* and *DIAMOND*—showed the Water Index of Taste ≥ 2.0 and the Water Index of Health ≥5.2, which we classified as tasty/healthy water. *Sam Da Soo* and *NamiNeral* can be classified as tasty water due to their values of the Water Index of Taste ≥ 2.0 and the Water Index of Health < 5.2.

The "Tasty Water Research Association" of the former Japanese Health and Welfare Ministry quoted in this study works to ensure Japanese water that Japanese people regard as tasty. However, the South Korean PET bottled water studied here fulfills the "Water Index of Taste," "Water Index of Health," "Standard for Tasty Water" and "Prerequisites for Tasty Water" that Japanese people value for city water. When we consider this and the fact that these brands of water are sold in LOTTE Mart, a respected supermarket in Korea, we can conclude that bottled water which meets water quality requirements will be considered good-tasting by a majority of people, since good-taste in water is universal.

The authors declare no conflict of interest.

REFERENCES

1 Choi Y, Sasaki H, Sugahara T. Properties of Korean natural mineral water. Journal for the integrated study of dietary habits. 1998;9:64-73. DOI: 10.2740/jisdh.9.64. Japanese with English Abstract.

2 Houri D, Morimoto M, Matsumoto K. Water Quality Evaluation of Natural Mineral Water by Mineral Balance. Journal of Japan Biological Society of Water and Waste. 2006;42:207-13. Japanese with English Abstract.

3 Houri D and Yoshioka S. Mineral-balance-oriented quality evaluation of waters of clear springs neighboring Mt. Daisen, Japan. Health Sciences. 2004;20:312-21. Japanese with English Abstract.

4 Satoh M. [Introduction to sensory test]. Tokyo: JUSE Press, Ltd.; 1983. p. 63-9. Japanese.

5 Hashimoto S, Furukawa K, Minami J. Studies on the water quality evaluation of drinking waters based on mineral balances (I) Preparation of mineral waters and their sensory test. Jpn. J. Water Treat. Biol. 1985; 21:19-24.DOI: 10.2521/jswtb.21.2_19. Japanese.

6 Hashimoto S, Fujita M, Furukawa K, Minami J. [Studies on the water quality evaluation of drinking waters based on mineral balances]. Water purification and liquid wastes treatment. 1988;29:13-28. Japanese.

7 The "Tasty Water Research Association." [Palatable water.] JWWA. 1985;54:76-81. Japanese.

8 Japan water works association. [Standard Methods for the Examination of Water and Commentary 2001]. Tokyo: Japan water works association; 2001. 827 p. Japanese.

9 Hashimoto S. Evaluation of water quality of healthy and/or tasty drinking water and its application to Japanese waters. The society of heating air-conditioning and sanitary engineers of Japan. 1989;63:463-8. Japanese with English Abstract.
10 The environmental news [Internet]. Tokyo: Kankyoshimbun-sha, Co., Ltd; 2008 May 28 [cited 2015 May 25]. Available from: http://www.kankyo-news.co.jp/ps/qn/guest/news/show-body.cgi?CCODE=81&NCODE=17 (2008/05/28). Japanese.
11 dagegawa [Internet]. gijangsoo; [updated 2013 June 6; cited 2015 July 10]. Available from: https://www.youtube.com/watch?v=6VO1Ns07THA.